HIGH SCHOOL PHYSICS AND THE ADOLESCENT

BY

LEWIS WARD WILLIAMS
Ph. B. Hiram College, 1909

THESIS

Submitted in Partial Fulfillment of the Requirements for the

Degree of

MASTER OF ARTS

IN EDUCATION

IN

THE GRADUATE SCHOOL

OF THE

UNIVERSITY OF ILLINOIS

1918

UNIVERSITY OF ILLINOIS

THE GRADUATE SCHOOL

October 2, 1918

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY Lewis Ward Williams

ENTITLED HIGH SCHOOL PHYSICS AND THE ADOLESCENT

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF Master of Arts in Education

W W Charters
In Charge of Thesis

W W Charters
Head of Department

Recommendation concurred in:*

Committee on Final Examination*

*Required for doctor's degree but not for master's.

TABLE OF CONTENTS

HIGH SCHOOL PHYSICS AND THE ADOLESCENT

A thoro acquaintance with the physical environment in which one lives, adds much of joy and efficiency to life. It would therefore seem that this factor should receive due consideration in the training of our young people. Woodhull[1] claims they have a desire for a knowledge of things physical, very strongly implanted in them. Hall[2] says this desire is particularly manifest at the beginning or during the early part, of the adolescent period. Of all the subjects which deal with this particular field probably physics is the chief. In the words of Hall,[3] "It conditions, perhaps, man's most fundamental views about his world." Hence, we may infer that physics is a subject peculiarly well suited for inclusion in a curriculum for adolescents.

This seems to have been an accepted fact as early as the beginning of our academies and high schools, for we find physics or natural philosophy, as it was then called, taught therein from the very first. Mann[4] says - "It was introduced into the schools for a specific purpose, namely, to

1. Woodhull - Teaching of Physical Science. Teachers College Record, Vol. XI, p.2.
2. Hall - Adolescence. Appleton, 1916. Vol. 2, p. 144.
3. Hall - Adolescence. Appleton, 1916. Vol. 2, p. 154.
4. Mann - Teaching of Physics. Macmillan, 1912. p. 38.

supply the common people with information about physical phenomena, and it <u>did</u> supply the desired information." However, from 1872 on, when the colleges began to exert a dominating influence over our high schools, the nature of the physics taught has changed considerably. The claim is made that the practice, if not the theory underlying it, has gradually assumed the nature of the university course; that the emphasis has been shifted from the popular and practical to the theoretical, technical and logical phase.

One factor in this change has been the American ideal that there should be a general system of education, ascending regularly from the district school to the university. Naturally, then, a course of study was desired which would lead to college. Since the college defined its entrance requirements, it could exert a strong influence on the high school course. Mann says by 1876 the schools had fallen completely under the spell of this idea.

About this time, a period of educational activity arose which resulted in a great desire for research work. This was particularly manifest in colleges and universities. Teachers developed under its influence carried over into the high schools, ideas of accurate measurement and logical form. In 1887, Harvard University published a list of laboratory experiments to define that part of the work in physics which would be accepted for entrance.

This had a very helpful influence in furnishing something definite as a standard for the formulation of high school

courses. This guidance was very much needed and was very generally accepted. However, the nature of the course offered was not so wholesome in its effect. Patterned after the advanced courses, it soon assumed many of their characteristics. This influence was further increased by the action of several apparatus companies which at once put on the market outfits for "doing" all the experiments in the Harvard list. The practice of using such apparatus and the set directions accompanying each experiment, tended to destroy the natural freedom and originality of the pupil.

The Committee of Ten very effectually fostered this entire tendency when it unanimously reported that physics should be taught in the same way, whether the pupil intended to go on to college or not.

Two factors remain to be discussed,--insistence on the inductive method and texts written by university men. The inductive method was insisted upon, says Mann,[1] for two reasons:

1. "Because, consciously or not, we must use inductive methods all our lives........"; and 2, "Because in the opinion of many teachers, more physics can be taught so as to be remembered, in this way than in any other." In spite of recognized obstacles to its use, it was quite generally tried and tended further to direct the course away from its original aim - "to supply information about physical phenomena."

During the period from 1872 to 1900, competent teachers of physics in high schools were very scarce. Practically

1. Mann - The Teaching of Physics. Macmillan, 1912. p. 48.

none were fitted to write a high school text. Thus, very naturally, the college and university men assumed this duty. In keeping with the general tendency, these books were permeated with the spirit of the college and university courses, though usually organized in a condensed and more elementary form.

Whether or not this charge of specialization is true, we do know that physics as a high school subject is not popular among high school pupils and that it has been slowly losing ground for the last 25 years. This is plainly shown by statistics taken from the 1916 Report of the United States Commissioner of Education, given in Table I on following page.

TABLE I

Actual and Percentage Enrollment in Four High School Subjects

1890	%	1895	%	1900	%	1905	%	1910	%	1915	%	
100144	33.62	205006	43.76	314856	49.97	391067	49.69	405502	49.59	503985	39.03	Latin
59781	20.07	114813	24.51	168518	26.75	219083	27.84	252404	30.87	346064	26.80	Geometry
63644	21.36	103768	22.15	118936	18.88	123282	15.66	120910	14.79	184426	14.28	Physics
82909	27.83	162336	34.65	238134	37.80	318775	40.50	455200	55.67	664478	51.46	History

In this table, for each year designated, the left-hand column contains the number of pupils actually taking the particular subject. The right-hand column gives the percent that this number is of the entire enrollment of the high schools tabulated.

The fact that physics is losing ground, becomes very evident when we contrast its record during this period with that of Latin for the same time. Latin has more than held its original position while physics shows a slow but steady decrease. The parallel holds for geometry and history.

It is true that all of these subjects show a slight decrease since 1910. This is a general movement, however, and is doubtless due to the enrichment of the curriculum through the addition of vocational subjects. This change has been manifest over the country as a whole, particularly from 1910 on. This slowly decreasing percentage for physics is therefore particularly significant when we remember that the teaching of Latin and geometry, as required work at least, has been seriously questioned for some time while the prominence and increasing importance of science have tended to emphasize the value of physics and the other sciences, as high school subjects. Evidently, then, this is a condition which demands attention if physics is to take its proper place in the high school. This necessitates an accurate knowledge of existing conditions as a basis. Only in this way can the truth or falsity of the criticisms suggested above be ascertained, or other weaknesses if they exist, be made known. This study is an attempt to meet this requirement.

Four sources of information have been used - a questionnaire to representative North Central Association high schools; the most commonly used texts in the schools reporting; some semester examination questions which were used in typical Illinois high schools; and a second questionnaire to 100 prominent college and high school physics teachers.

The questionnaire to North Central Association schools was formulated by the Committee on Reorganization of Secondary Schools and Definition of the Unit. The fact that it was to be for all high school subjects rather than for physics in particular, makes it very objectionable in a number of respects. These will be mentioned in the discussion of the results of the questionnaire bearing particularly upon them.

NORTH CENTRAL ASSOCIATION
OF COLLEGES AND SECONDARY SCHOOLS
Committee on
Reorganization of Secondary Schools
and
Definition of the Unit
Inquiry in . . . .
(Fill in subject)

1. Name and location of school . . . .
2. Name of teacher. . . . .
3. Years, including the present, teacher has taught the subject in this school . . . .
4. Year in the high-school course in which the subject is taught
5. What aspects of the subject, or of your particular course in the subject, recommends the subject for the year stated under 4?. . . . .
6. From what other high-school years may the student elect the subject?. . . . .
7. Time used in course:
   (a) Number of weeks . . . .
   (b) Number of recitation periods per week . . . .
   (c) Number of laboratory periods per week . . . .
       Length of each period. . . . .
   (d) Number of field trips . . . .
   (e) Time length of field trips. . . . .

8. Indicate by CHECKING and by added statements what are the purposes of the course:
   (a) To present a comprehensive and unified organization of the subject.
   (b) To develop the particular quality of intellectual training which this subject makes possible.
   What do you regard this particular training to be? . . . .
   (c) To relate the subject to problems of environment, such as those of agriculture, domestic science, industry, etc.
   Why? . . . .
   (d) State any other definite aims in your mode of teaching the subject . . . .
9. Organization of the course:
   (a) What textbook or books do you use? . . . .
   (b) What, if any, laboratory manual is used? . . . .
   (c) Do you follow any syllabus? . . . .
   What one? . . . .
   (d) What important deviations do you make in your course from the plan of the course given in text or syllabus named? . . . .
   (e) Do practical illustrations precede, accompany, or follow development of the principles involved?
   Why? . . . .
10. State any other distinctive features of your course . . . .

The main facts obtained from the returns to this questionnaire seem to be -

1. High school physics is a fourth-year subject, not a third. The large majority of the teachers reporting, favor this position.

2. (a) High school physics is distinctly a one-year subject. No schools report less than a year and only two report an additional semester.

(b) Recitation time per week varies widely - from 80 minutes to 250 minutes. The most common practices are 3 recitations of 40 minutes each and 3 of 45 minutes each.

(c) Laboratory time per week also varies widely - from 45 minutes to 360 minutes. The most common practices are 2 periods of 80 minutes each and 2 of 90 minutes each.

(d) Similarly, the total time per week varies widely - from 160 minutes to 500 minutes. The most common practices are 280 minutes and 315 minutes. It is very evident that some schools devote twice and even thrice as much time to this subject as others.

(e) Slightly more than one half of the schools have observation or field trips.

3. There is remarkable agreement in regard to the aims suggested in the questionnaire - (a) To present a comprehensive and unified organization of the subject: (b) To develop the particular quality of intellectual training which this subject makes possible; (c) To relate the subject to problems of environment, such as those of agriculture, domestic science, industry, etc. Little agreement was manifest in regard to what this "particular training" might be. Similarly, there was little agreement in regard to any other definite aims.

This unanimity of aims can doubtless be explained on the grounds that they are very general in nature. In fact, they are so general that they really mean nothing. However, when the teachers were asked to explain or make these more definite, little material of value was received. This may be quite significant in that perhaps our physics teachers have indefinite or general aims, if they consciously use any at all. Doubtless, several specific and definite aims should have been formulated, and reaction to these called for.

4. The organization and content of the course seem to be determined in nearly all schools by the textbook used. Devia-

tions given are almost without exception of minor consequence.

5. There is no agreement as to whether practical illustrations should precede, accompany, or follow the development of the principle involved. Reasons given for the practices followed were just as variant, and, strangely enough, were given to justify each of the seven which were possible.

The findings of the questionnaire will now be discussed in detail. One hundred fifteen schools responded to the questionnaire. These were distributed quite uniformly over the states comprising the North Central Association, as follows: Indiana, 13; Michigan, 11: Montana, 2; Ohio, 16; Wisconsin, 12; Colorado, 5; Iowa, 5; Minnesota, 7; Nebraska, 2; Oklahoma, 2; Illinois,21; Kansas, 11; Missouri, 5; North Dakota, 2; and South Dakota, 1.

Probably conclusions drawn from the study ought not to be too much generalized though doubtless the schools reporting, both large and small, represent a very cosmopolitan population. Certainly, all the industries are represented in the area covered, and thus we may infer that all conditions, from backward to highly progressive, are reflected in the work of these schools.

Of the teachers reporting, 20 were teaching the subject for the first year in the school from which they reported; 26, their second year; 12, their third; 7, their fourth; 13, their fifth; 7, their sixth; 5, their seventh; 8, their eighth; 6, their ninth; 5, their tenth; 4, their twelfth; 1, his thirteenth and 1, his twenty-fifth. This means that 60% of the teachers who reported have taught at least 2 years where they are now employed and that 82% have taught there at least one year.

This question, "Years, including the present, teacher has taught the subject in this school," should have been expanded to include the total experience of the teacher and his experience in physics teaching. This would have permitted weighting of definite suggestions by the individual teachers.

The teacher is the most important factor concerned. Given a good teacher, other conditions being average or even inferior, we may expect satisfactory results. A study of the rating of physics teachers as compared to other teachers in the schools, considering such factors as professional training, experience, personality and enthusiasm, would make the general problem much more specific. Doubtless there is some relation between good work and factors such as text, equipment and time expended on the subject. If this were determined, even approximately, the main problem could be limited in such a way as to permit of more specific treatment.

In sixty-nine schools, physics is taught in the fourth year; in 37, in the third year; in 8, in either the third or fourth; in one in the second year. Of the 69 schools offering it in the fourth year, 33 permit its election in the third if certain prerequisites, such as one year of algebra and one year of plane geometry, have been met. Thirty-three of the 37 schools offering it in the third year, permit its election in the fourth year.

In seven of the 27 schools offering it in the third year, the claim is made that it was placed there as a preparation for chemistry; in eight, that the pupil has then had enough math-

ematics to begin the subject; and in three, that it is there for the benefit of those who leave at the end of the junior year. The school offering physics in the second year does so that those who leave before the junior year may receive some work in this subject.

Reports from the schools offering physics in the fourth year likewise show various reasons for this position. Thirty-seven stress the need of more maturity; 42 mention the mathematics required; and 7, the assistance gained from science work already taken. Some say that it could be offered in the third year just as well and one insists that chemistry is more easily grasped than physics.

The amount of time given to the subject varies widely among the schools reporting.

(a) The course is 34 weeks long in one school; 36 weeks in 62 schools; 37 weeks in 2 schools; 38 weeks in 27 schools; 39 weeks in one school; 40 weeks in 19 schools; 42 weeks in one school and 54 weeks in two schools.

(b) Recitation time per week varies from 2 periods of 40 minutes each to 5 periods of 50 minutes each. Thirty-seven schools have 3 periods of 45 minutes each; 25 have 3 of 40 minutes each; 13 have 4 of 45 minutes each; 10 have 5 of 45 minutes each; 6 have 5 of 40 minutes each; and 4 have 4 of 40 minutes each. The few remaining vary widely both in number of recitations and in their length.

TABLE II

Distribution of Recitations and Time

Schools Reporting	Number of Recitations	Length of Each	Time per Week
2	2	40'	80'
1	2	60	120
1	2½	40	100
25	3	40	120
3	3	42	126
1	3	44	132
37	3	45	135
1	3	48	144
1	3	55	165
2	3	60	180
1	3	65	195
1	3	80	240
4	4	40	160
1	4	42	168
13	4	45	180
1	4	55	220
1	4	60	240
6	5	40	200
10	5	45	225
1	5	50	250

(c) The time devoted to laboratory work varies from none at all to 2 periods of 180 minutes each per week. Twenty-six schools have 2 periods of 90 minutes each; 18 have 2 periods of 80 minutes each; 11 have one of 90 minutes; 5 have 4 of 40 minutes each; 5 have 4 of 45 minutes each; and 5 have one of 80 minutes. The remaining schools differ widely both in number of periods and in their length.

TABLE III

Distribution of Laboratory Periods and Time

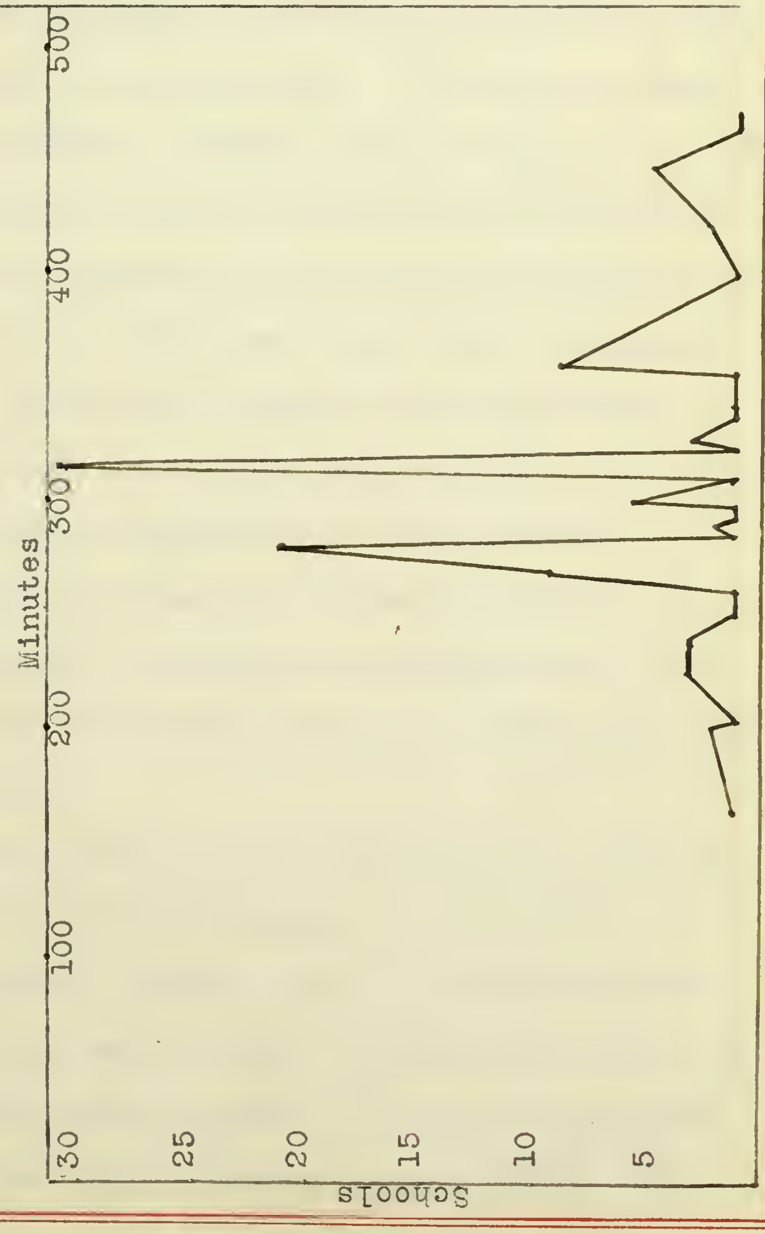
Schools Reporting	No. of Lab. Periods	Length of Each	Time per Week
1	0	0	0
1	2	40	80
5	4	40	60
1	5	40	200
1	4	42	168
1	1	45	45
4	2	45	90
1	2½	45	112.5
4	3	45	135
5	4	45	180
4	5	45	225
1	6	45	270
1	5	50	250
4	2	60	120
1	3	60	180
1	2	65	130
5	1	80	80
18	2	80	160
1	2½	80	200
2	3	82	246
1	2	83	166
1	1	84	84
1	2	85	170
1	2	86	172
1	2	87	174
1	2	88	176
11	1	90	90
26	2	90	180
2	2	95	190
1	2	96	192
1	1	115	115
1	1	120	120
2	2	120	240
1	2	180	360

(d) The total time per week given to this subject varies from 160 to 500 minutes. One school gives 160, and one, 500 minutes. Thirty-one give 315 minutes; 21, 280 minutes; 9, 270 minutes; 6, 300 minutes and 5, 450 minutes. Very few of the remaining 35 schools compare closely; rather are they well scattered from one of 200 minutes to one of 495 minutes.

TABLE IV

Distribution of Time Devoted to Physics

No. of Schools Reporting	Total time per Week
1	160
2	200
1	205
3	225
3	240
1	252
1	255
1	260
9	270
21	280
1	286
2	290
1	294
1	298
6	300
1	308
31	315
1	320
3	325
1	336
1	337.5
1	355
9	360
1	400
2	420
5	450
1	495
1	500



(e) Twenty-seven schools have no field or obervation trips and 25 fail to answer, so probably they do not. The remainder of the schools have from one, of a half day's length, to ten of an hour each. In most schools nothing very definite is planned in this respect. Power plants, saw mills, flour mills, ice plants, electric light plants, laundries and water works are places most commonly visited.

The first aim given in the questionnaire - "To present a comprehensive and unified organization of the subject" - received the approval of 90 teachers. Several approved of it with a condition appended, such as the following: "As far as possible", "in a measure" and "hardly possible in high school physics."

One hundred and one teachers approved the second aim - "To develop the particular quality of intellectual training which this subject makes possible." There was very little agreement, however, as to what this particular quality of intellectual training is. Observation was named 22 times; accuracy, 23 times; reasoning, 31 times; practical application of mathematics, 8 times; intelligent interest, 5 times; suspended judgment, 11 times; impersonal conclusions, 14 times; acquaintance with environment, 11 times; scientific investigation, 23 times; and how to attack a problem, 5 times.

Ninety-six teachers agreed to the third aim - "To relate the subject to problems of environment, such as those of agriculture, domestic science, industry, etc." In response to the question of why this aim was favored, increased interest was named 15 times; correlation made possible, 7 times; helps practical application, 48 times; understanding of environment, 35

times; and helps observation, 4 times.

The request for other aims brought no answer from 60 teachers. The answers given by the remaining 55 teachers were very varied. Mental discipline was named 11 times; meet a problem and solve it, 9 times; insight into nature, 6 times; accurate thinking, 11 times; preparation for college, 5 times; character building, 3 times; observation, 4 times; and honesty, twice.

The textbooks used in these schools are as follows: Millikan and Gale, 44 schools; Carhart and Chute, 23 schools; Mann and Twiss, 5 schools; Reed and Henderson, 4 schools; Adams, 1 school; Cullers, 1 school; several, 2 schools. Nineteen different laboratory manuals were mentioned. The Millikan and Gale or Millikan, Gale and Bishop manual is used in 32 schools; Black in 14 schools; Fuller and Brownlee in 8 schools; Smith, Tower and Turton in 6 schools; Gorton in 3 schools; Reed and Henderson in 4 schools. Ten schools use no manual, 14 use their own based on several manuals, and 19 schools use 13 other manuals.

Sixty-three teachers say they do not follow a syllabus and 24 do not answer; thus probably we may infer that they do not, making 87 in all. Three teachers use their own, 2 follow a city syllabus, 9 follow a state syllabus and 2 follow a syllabus issued by a state university.

About 40 schools offer deviations in their courses from the plan suggested in the text or syllabus used. For the most part, these are of minor consequence. Change of order of topics is mentioned 14 times; omission of light and sound, once; omission of certain phases of some topics, 10 times; supplementary work,

8 times; and stressing own central power plant, 3 times.

Thirteen teachers give practical illustrations of the principle before it is developed; 32 have the illustrations accompany the development; 11 have them follow the development; 4 usually have them precede but sometimes accompany or follow the development; 3 usually have them follow but sometimes precede or or follow the development; 2 usually have them follow but sometimes precede or accompany the development; and 50 use any of the three main ways, depending upon the circumstances. The reasons given for the position of the practical illustrations, are numerous and are frequently used to justify each of the various practices. "It adds interest," "it promotes apperception" and "it is most logical" are typical answers.

In response to the suggestion to name "Other distinctive features" of the courses, 51 teachers mentioned 25 different ones. Some of those which seem most important from the standpoint of modern ideas in physics teaching are: Life-size apparatus, when possible; supervised study; emphasis upon practical illustrations; individual laboratory work; one 45-minute period per week for the discussion of experiments performed in the laboratory; industrial survey of the community; separate classes for boys and girls; wireless club; camera club; third semester of practical work; and discussion of questions in physics by members of the class, before the school as a whole. This question as stated, leaves too good an opportunity to omit it. Preferably, a number of these features should have been given with directions to check, though it is doubtless advisable to give opportunity for further suggestions, or even explanations of those checked.

Since it seemed a safe inference that the organization and content of the course are determined in most schools by the textbook used, the next logical step appeared to be a careful study of those texts. The six chosen for this purpose were used in 104 of the 115 schools answering the questionnaire; 3 of these texts were used in 89 schools. Twenty-two topics, so chosen as to cover the field well, served as a basis for analysis. In this manner, some idea of the relative prominence of these topics in the various texts, was obtained. The figures in the table indicate the percent of the entire book that was devoted to the particular topic.

TABLE V

Analysis of Texts

	Mann and Twiss	Reed and Henderson	Gorton	Carhart and Chute	Black and Davis	Millikan and Gale
Molecular Physics	6½	8	3	5½	5	9½
Hydrostatics	5	5	6	5	6	4½
Pheumatics	2½	5	6	5½	5	5½
Force and Motion	7	9	12	8½	9	5
Gravity	4	2	1½	1½	1½	1
Work and Energy	11	2½	4	3	5	4
Machines	5	3	3½	3	5	3
Heat (general)	5½	7½	5½	5½	5½	6
Calorimetry	1	1	1	1	1	½
Heat and Work	7	1½	2½	2	4	5
Change of State	1	3	3	2	2½	3½
Magnetism	1	3	3	3	2	2½
Static Electricity	3½	4½	5	5	3	5
Current Electricity	8½	14	13	13	13	10½
Electro-Magnetic Induction	8½	7	9	9	13	11½
Sound (general)	3	5	3½	3½	2½	2½
Waves and Wave Motion	1½	2	1	1	1	1½
Music and Musical Instruments	3½	3½	6	6	3	5
Light (general)	9½	8	8	8	7½	8
Lenses	3	2	2½	2½	1½	1½
Mirrors	2	2½	2½	2½	2	1½
Optical Instruments	4½	2	1½	1½	2½	2½

The Mann and Twiss text shows more variation than any other one. For example, it gives relatively only about one half as much attention to "pneumatics" as the others; fully twice as much to "gravity"; from two to three times as much to "work and energy"; scarcely half as much to "magnetism"; and about twice as much to "optical instruments." However, this text was used in but 5 of the 115 schools.

The Millikan and Gale, Black and Davis, and Carhart and Chute texts compare quite favorably in this respect, a few exceptional topics being "molecular physics," "force and motion," "machines," "static electricity," "electro-magnetic induction," and "mirrors." These variations are not great, however, and it seems safe to say that they occur in important topics. In any case, then, the topic has received considerable emphasis. However, too much dependence must not be placed upon this basis of comparison, because without doubt correlation and treatment differ considerably.

In general arrangement, the Gorton text is very similar to the Millikan and Gale text. The style in Gorton is clear and the problems are well chosen. In the Carhart and Chute text, the problems are more difficult and the treatment plenty hard and technical. Both are mathematical, scientific, and treat physics as the science of matter and energy, stressing both phases thoroughly. The Millikan and Gale text gives more attention to energy and energy changes, though matter receives considerable attention. This text is extensive, logical and well presented but probably has too much theory for the first year's work.

In the Black and Davis text, the emphasis is placed on

energy rather than matter. The book is full of topics of vital interest to young people. The presentation, from the standpoint of energy, if possible, is usually simple and direct. The problems are not as close to the affairs of every-day life as the general plan of the book would warrant. The Mann and Twiss text has been called the "exponent of the new physics." Here energy and energy changes receive very prominent attention. The style is clear throughout. Algebraic formulas and equations have been practically omitted. It therefore requires less mathematics than the others. There is very little theory in the book; on the contrary, every effort has been made to introduce the concrete and practical. Unless the work is supplemented somewhat, the laboratory work to go with this text should be considerably different than that for the others.

This study of texts reveals that they are condensed forms of an extensive field and therefore are organized from the logical standpoint; that the authors, with very few exceptions, are university men; that theory has been very prominently stressed; that the treatment is technical and mathematical rather than popular, though recent books, notably the Black and Davis text and the Mann and Twiss text, show a big improvement in this respect.

Tests or examinations are so universally used in our high schools that they constitute a very important feature of our teaching. Hence it seemed advisable to get some data dealing with examination questions in physics. For this purpose, (examination) questions used in Illinois high schools and collected by the late Dr. C. H. Johnston in the spring of 1914 were used. These lists

were analyzed and questions or parts of questions classified as well as possible under the following heads: Observation; rote memory; logical memory; concept, judgment, reasoning and speculative ability.[1] Briefly stated, observation as here used means ability to see and report things as they actually are; rote memory,-skill in reproducing literally, forms of speech, definitions, sentences, paragraphs of texts, etc., without attention to the meaning; logical memory,-ability to recall explicitly the consecutive steps of some former exposition of a topic or to give a clear logical report of series of organizations of past impressions; concept,-ability to grasp the significance of a situation, a principle, etc.; judgment,-ability to make a reliable decision, demonstration of good common sense; reasoning,-capacity for syllogistic thinking and expertness in noting likeness - difference relations, cause and effect, etc.; speculative ability - ability to organize experiences to meet new situations. Questions were classified according to the type of ability they called forth. Frequently, it was necessary to put part of a question under one head and part of it under another. Judging from the questions examined, there is no necessity for speculative ability in a scale of this kind. The data here given are for 14 lists from actual Illinois high schools and were worked out by the writer during the summer of 1914. They compare very favorably with results obtained in a rather comprehensive study of this nature by John Breen Phillips.[2] (The figures in the table following

1. This scale was arranged by Dr. Johnston.
2. See unpublished Master's thesis, 1916, University of Illinois.

indicate the number of questions under each head. The last column is an exception to this; here, the figures indicate the percent of the total number of questions which is given to each classification).

TABLE VI

Analysis of Examination Questions

Observation	1	0	1½	0	½	1	0	0	1	2	½	1	½	½	9½	6½
Rote Memory	1½	4	3	5½	3½	3½	2	2	3½	3½	4	3	4½	2	45½	31½
Logical Memory	2	3	5½	2½	3	2½	2	1	2	3½	3½	2	3	3	38½	26½
Concept	1	1	0	1	0	0	0	0	2	1½	1½	1	½	½	9½	6½
Judgment	2	1½	0	0	0	0	1	0	0	0	0	0	1	0	5½	3.8
Reasoning	2½	3½	3	3	4	3	1	1	1½	2	2½	3	2½	4	36½	25
Speculative Ability	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total Questions	10	13	13	12	11	10	6	4	10	12	12	10	12	10	145	

From these data, one seems warranted in drawing the following general conclusions: (1) Too much stress is placed on rote memory; too little on concept, observation and judgment; (2) reasoning seems to receive a fair amount of attention, in many cases unnaturally so, however; that is, by unnatural problems. The lists seem to be extremely academic, though undoubtedly the trend of modern physics is away from this characteristic. On the other hand, examination questions should conform quite largely to the type of teaching or they are unfair to the pupil. If they do conform to the type of teaching, and this seems a safe assumption, our methods of teaching are the potent factor here. A summary of the study thus far will now follow.

There is a high degree of standardization in physics teaching in these 115 schools. This is indicated by the high agreement in regard to aims as well as by the time per week devoted to the subject. More than two thirds of the schools conform to one or the other of the two modal practices. Texts also compare very favorably, much more so than one might think possible especially those most generally used. The deviations from text or syllabus used are of minor consequence. Therefore, it seems quite certain that the organization and content of the courses are very similar. Even lists of examination questions show a high degree of correlation. Furthermore, they seem to indicate questionable methods of teaching. This may possibly be explained in part by the nature of the texts used since there seems to be close adherence to them, and in part to failure to adapt subject matter to pupils. Doubtless, the popular physics of the early days has been replaced by physics of a more technical and logical nature. Our next problem thus becomes a question of the desirability of standardization and a close analysis of methods.

Data on this phase of the work was obtained from the answers to a questionnaire sent to 100 prominent physics teachers, both high school and college.[1] These men were selected on the basis of prominence of institution with which they were connected and the reputations they had made for themselves in the field of physics. About 60% of the men chosen were college and university teachers and 40% high school teachers.

1. This questionnaire was formulated by Mr. F. D. Townsley of James Millikin University and sent out by him. He voluntarily turned it over to the writer for this study.

QUESTIONNAIRE

1. Of the "120 semester hours" in physics, how many should be standardized for all schools?

2. What parts of the physics course might be determined by "local needs"?

3. Do high school teachers of physics attempt to teach too many topics during the year?

4. Name topics in the teaching of which practically all the time is wasted.

5. Name five or more topics that are not sufficiently stressed.

6. Name five specific things that the student should be able to do in mathematics when he enrolls in the high school physics.

7. List briefly some of the weaknesses in high school physics teaching.

    a. In class work.
    b. In laboratory work.

8. List briefly some of the weaknesses in college physics teaching.

The main findings seem to be -

1. There is little agreement in regard to the extent that standardization is desirable. The few teachers answering, favor one half of the course or more.

2. Only a small part of the course should be determined by "local needs."

3. The tendency is to attempt to teach too many topics during the year.

4. There is very little agreement in regard to topics

which might profitably be omitted. Forty-one different ones were suggested.

5. There is little or no agreement in regard to topics which are not sufficiently stressed. Sixty-six different ones were named.

6. Much less mathematics is necessary for this subject than is generally supposed. There is practical agreement for ability in the fundamental operations in arithmetic, for ability to solve algebraic equations of one unknown; and for ability to use ratio and proportion.

7. Weaknesses in class work are primarily those of method, being violations of simple pedagogical and psychological principles.

8. Weaknesses in college physics teaching are of the same nature as those in high school.

9. Weaknesses in laboratory work can be classed as violations of method and of class management. University influence is evident here.

This questionnaire is much more definite and specific than the first. It deals primarily with two things - standardization and methods of teaching. Fifty-five answers to the questionnaire were received. But 30 of these dealt with the first question, "Of the 120 semester hours in physics, how many should be standardized?" Six teachers answered 120 hours; 5, 102 hours; 3, 90 hours; 5, 80 hours; 2, 60 to 90 hours; 7, 60 hours; 2, none. Inasmuch as 25 teachers refused to commit themselves on this point, this seems to be a debatable question. However, those answering agree that one half or more of the course should be

standardized. This question should have been followed by a request for reasons. This would have brought out a distinct relation, if any exists, between this factor and criticism of present-day high school physics.

Five teachers say no part of the course should be determined by local needs; 3, very little of it; 2, one half of it; 2, the entire course; 2, one fourth of it;and one, one third of it. Among the topics suggested that might be determined by local considerations were electrical appliances, named 3 times; heat, twice; machines, twice; methods of heating, twice; and work, mechanics, optical instruments, water systems, automobiles and eleven others, all of thich were named but once.

This question, "What parts of the physics course might be determined by 'local needs'?" was frequently answered by such statements as, "One tenth," "one fourth," and the like. Doubtless the purpose of the question was to ascertain the topics which "local needs" might determine. Hence, What topics in the physics course might be determined by "local needs?" would probably have been clearer.

Professor C. R. Mann,of Chicago University, says 100 topics are enough for a year's work. Eighteen teachers claim too many topics are attempted, 7 answer that this is probable,while 13 do not feel that this is true.

Question four was a poor one - "Name topics in the teaching of which practically all the time is wasted." Many resented this idea by saying - "There are none." It really should be a question of relative values. Granted that we attempt to teach too many topics during the year, which ones should be

omitted? However, it brought a ready and varied response. Forty-one different topics were named and 28 of these were mentioned but once. Harmonic motion was named 5 times; polarized light, 4 times; acceleration, 4 times; alternating currents, 3 times; static electricity, 3 times; electric generators, twice; inertia, twice; spectroscope and spectrum analysis, twice; absolute units, twice; radio activity, twice; wave motion, twice; and laws of motion, twice.

Sixty-six topics were named as not being sufficiently stressed though 45 of these were given but once. Mechanics was mentioned 6 times; alternating current experiments, 5 times; heating, 4 times; Ohm's Law, 3 times; hygrometry, 3 times; color phenomena, 3 times; nature of light, 3 times; principle of work, 3 times; and the following twice each - Sound, Joule's equivalent, energy changes, harmonic motion, ventilation, properties of matter, sound and music, gas engines, practical electrical measurements, molecular motion, chemical effects of electricity, waves, and motion.

Eleven topics were suggested as requiring more emphasis which were also named among those, in the teaching of which practically all the time is wasted. Harmonic motion was named 5 times in the first connection and twice in the second; waves and wave motion was named twice in each connection; acceleration, 4 times in the first and once in the second; and alternating currents, 3 times in the first and 5 times in the second. The others, named once in each connection were sound, light, properties of matter, Boyles' Law, Charles'Law, color theories and early definitions.

Among the specific things in mathematics that a pupil should be able to do when he enrolls in high school physics, the following received most frequent mention. Solve a simple algebraic equation of one unknown, was named 26 times; ratio and proportion, 19 times; fundamental operations in arithmetic, 17 times; square root, 11 times; simple algebraic equations of 2 unknowns, 9 times; similar triangles, 6 times; graphs, 5 times; common fractions, 4 times; and a little geometry, 4 times.

The seventh question dealt with weaknesses in high school physics teaching. It could have been made to contribute more effectively to our problem, had causes for these weaknesses been called for. However, a number of the teachers answering, gave this information or suggestions concerning it, voluntarily. Twenty-six specific weaknesses in class work were pointed out. Practically all of these were violations of cardinal principles of method. The ones here given, those most often mentioned, are typical. Stressing definitions rather than principles, unprepared teachers, and don't make subject real, were each given 6 times; indefinite assignments, 5 times; teacher talks too much, pupil too little, and lack of thoroughness, 4 times each. Other important ones were assigning too much, too few problems from life, copying university physics, take too much for granted, failure to correlate recitation and laboratory work, and lack of reviews.

The weaknesses in laboratory work were well distributed between method and class management. Twenty-five in all were given. Failure to require explanation of the principles involved in an experiment was named by 7 teachers; too many experiments,

by 6 teachers; lack of neatness and accuracy, by 6 teachers; experiments of no interest, by 5 teachers; insistence upon too small a percent of error, by 5 teachers; insistence upon following directions rather than principles, by 4 teachers; too much verification, by 3 teachers; and too much written work, by two teachers. Other important ones named were - work not systematized, teacher does too much, too large laboratory sections and too little planning ahead.

Most of the suggested weaknesses in college teaching were also given as weaknesses in high school teaching. Additional ones were too much theory, too technical, too much lecturing and too much work required. We may now summarize the results of this questionnaire.

Many of the teachers of most thorough preparation and longest experience feel that too much is expected of the pupils and that there is too little adaptation of the material to the pupil, from the standpoint of interest and the pupil's capacity. Most of these teachers also feel that the course should be more elastic, that not so much of it should be standardized. Primarily, however, the stress is placed upon methods of teaching and closely related problems such as scholarship and enthusiasm.

Criticisms of the same tenor have been, and still are, coming from outside the realm of physics proper. A number of years ago G. Stanley Hall wrote[1] - "The half score of textbooks in physics I have glanced over seem essentially quantitative, require great exactness, and are largely devoted to precise measure-

1. Hall - Adolescence - Vol. 2, p. 155. Appleton, 1916.

ments, with too much and too early insistence on mathematics...... The topics are no doubt admirably chosen, their sequence the best from a logical standpoint, and they are such models of condensation and enrichment that it seems to the organizer and the specialist alike, almost perversion that our youth pass it by. But boys of this age want more dynamics. Like Maxwell when a youth, they are chiefly interested in the go of things." Again he says,[1] "The subject matter of the curriculum is too condensed, too highly peptonized for healthful assimilation; and we are too prone to forget that we can only accelerate nature's way, but never short-circuit it, without violence."

Under the subject "The Reorganization of High School Science," Fred D. Barber of Illinois State Normal University says, "The day has passed when it was pertinent to ask whether high school science needs reorganization; high school science is now being reorganized. It behooves the adherents of "pure science" to wake up if they would have the best elements of the old regime preserved."

Thus it seems that the material used, its organization, and the methods of teaching have all been challenged. Doubtless the teacher himself is the most important factor involved but his work can produce the best results, only when a wise choice of material has been made, this has been properly organized from the standpoint of the interests and capacities of the pupils concerned, and effective methods of teaching are employed.

---

1. Hall - Adolescence - Vol. 2, p. 157. Appleton, 1916.

The main findings of the thesis are:

1. There is a high degree of standardization in high school physics teaching; most teachers feel there should be more liberty here, though probably one half or a little more of the course should be standardized.

2. Organization and content of the courses are largely determined by the texts used.

3. The texts most commonly used are technical, logical and mathematical.

4. These characteristics of the texts are reflected in the examination questions used and in the criticisms of the methods of teaching.

5. Poor teaching is due to lack of professional training rather than to lack of knowledge of subject matter; more specifically, to failure to adapt material to pupils and to make it personally real and worth while.

6. There is a tendency to swing back to the original idea in physics teaching - to stress the popular and the practical.

7. This indicates that physics teachers are beginning to realize the gravity of the situation in which physics now stands and to show a willingness to follow constructive leadership.

BIBLIOGRAPHY

Black and Davis - Practical Physics, The Macmillan Company.

Brown - The Making of Our Middle Schools, Longmans, Green and Company.

Carhart and Chute - First Principles of Physics, Allyn and Bacon.

Gorton - High School Course in Physics, Appleton and Company.

Hall - Adolescence, Appleton and Company.

Mann - The Teaching of Physics, The Macmillan Company.

Mann and Twiss - Physics, Scott, Foresman and Company.

Millikan and Gale - A First Course in Physics, Ginn and Company.

Reed and Henderson - High School Physics, Lyons and Carnahan.

Report of United States Commissioner of Education, 1916.

Twiss - Science Teaching, The Macmillan Company.